Infrastructure and economic development

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"[T]he sovereign has only three duties to attend to; three duties of great importance […] Thirdly, the duty of erecting and maintaining certain public works […] which it can never be for the interest of any individual, or small number of individuals, to erect and maintain; because the profit could never repay the expence to any individual or small number of individuals, though it may frequently do much more than repay it to a great society."

Adam Smith, *Wealth of Nations*, Book IV.
Motivation

Why infrastructure? Two reasons

• Growth
  – Development of core infrastructure (transport, power, telecom) raises output and the productivity of other inputs (labor, non-infrastructure capital)

• Poverty / inequality
  – Infrastructure development may have a disproportionate effect on the income / welfare of the poor – by widening their economic opportunities
A comparative perspective

Overall infrastructure quality

(7 = best)
A comparative perspective

Quality of electricity supply

(7 = best)
A comparative perspective

Road quality

(7 = best)
4.1.1 Infrastructure Stock and Economic Growth

Growth in real GDP per capita (%) vs. Aggregate Index of Infrastructure Stocks, IK1 (in logs)

\[ y = 0.4812x + 1.6724 \]
\[ R^2 = 0.1701 \]
Not only the quantity -- the quality of infrastructure also matters.

4.1.2 Infrastructure Quality and Economic Growth

\[ y = 0.6312x + 1.8891 \]

\[ R^2 = 0.2054 \]
Figure 3. Infrastructure Stocks vs. Income Inequality

\[ y = -0.0303x + 0.403 \]
\[ R^2 = 0.2157 \]
Figure 4. Infrastructure Quality vs. Income Inequality

Gini Coefficient (0-1)

Infrastructure Quality (1st. Principal Component)

\[ y = -0.0523x + 0.3887 \]

\[ R^2 = 0.2942 \]
Infrastructure and growth

How does infrastructure affect growth?

• As another productive input – just like labor or non-infrastructure capital
  – Direct + indirect effect if inputs are gross complements (from Arrow and Kurz 1970)

• By reducing the cost of accumulating other inputs
  – E.g., lower the cost of installing new capital (Turnovsky 1996) or accessing education

• Through spillover effects on TFP
  – More efficient organization of production (Duggal et al 1999)
  – Lowering the cost of innovation and technological upgrading (Bougheas et al 2000, Agenor 2013)
Infrastructure and growth

How big is the impact of infrastructure on growth?

• Big literature after finding of huge effects in the US (Aschauer 1989)

• Reverse causality a big problem – demand for infrastructure services typically rises with income growth
  – Can lead to overstated growth effects of infrastructure supply
  – Identifying information needed to separate demand and supply effects (internal / external instruments; full structural models)

• Infrastructure measurement also an issue
  – Physical assets vs investment flows (or their accumulation)
  – Multidimensionality of core infrastructure – transport, power, telecom…Synthetic indices of physical assets as an alternative
Infrastructure and growth

Two common approaches with macro data:

– Infrastructure as another input in the aggregate production function (or its dual, the cost function)
  • Along with human and non-infrastructure physical capital
  • Typically focus on direct effects only – holding other inputs constant

– Growth regressions augmented with infrastructure measures
  • Along with other determinants of long-run growth: trade openness, fiscal policy, structural features
  • Usually yields total effects – allowing for changes in other inputs

Also some sector and firm-level studies
  • e.g., electification and roads programs in India
Infrastructure and growth

A majority of studies find sizable positive effects
– Especially recent studies of developing economies
– And studies using physical indicators (e.g., km of roads)
– But not those using infrastructure spending
  • owing to spending inefficiency and waste (Tanzi and Davoodi 1997; Pritchett 2000; Keefer-Knack 2007; Collier 2015)

Growth effect of infrastructure:
empirical studies by reported finding (Straub 2007)

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Negative</th>
<th>None</th>
<th>Positive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Capital (65)</td>
<td>10.8%</td>
<td>40.0%</td>
<td>49.2%</td>
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<tr>
<td>Physical Indicator (75)</td>
<td>1.3%</td>
<td>24.0%</td>
<td>74.7%</td>
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</table>
Production function approach

- Infrastructure elasticity estimates center around 0.10
- Implied output effects are economically significant

Projected effect of infrastructure catch-up to OECD median (direct effect only – holding physical and human capital constant)

<table>
<thead>
<tr>
<th>Region</th>
<th>Increase in output per worker</th>
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<tbody>
<tr>
<td>East Asian Tigers</td>
<td>11.5%</td>
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<tr>
<td>Eastern Europe</td>
<td>8.3%</td>
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<tr>
<td>Latin America</td>
<td>13.7%</td>
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<td>Middle East &amp; N. Africa</td>
<td>15.5%</td>
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<tr>
<td>South Asia</td>
<td>26.0%</td>
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<tr>
<td>Sub-Saharan Africa</td>
<td>36.3%</td>
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</table>
Country-specific estimates of the infrastructure elasticity of output
(Synthetic Infrastructure Index)

Source: Calderón and Servén 2012
## Growth regression approach

<table>
<thead>
<tr>
<th>Study</th>
<th>Countries</th>
<th>Years</th>
<th>Infrastructure Measures</th>
<th>Growth effect of a 1% increase in infrastructure measure (percentage points)</th>
</tr>
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<tbody>
<tr>
<td>Calderón and Servén (2009, 2011)</td>
<td>97</td>
<td>1960-2005</td>
<td>Synthetic index of physical infrastructure quantities (power, transport, telecom)</td>
<td>2.19**</td>
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<td></td>
<td>Synthetic index of infrastructure quality (power, transport, telecom)</td>
<td>1.96**</td>
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<td>Loayza et al (2010)</td>
<td>78</td>
<td>1961-2005</td>
<td>Electricity index</td>
<td>0.75**</td>
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<td>Transport index</td>
<td>1.09**</td>
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<td>Telecom index</td>
<td>1.10**</td>
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Growth changes across regions due to infrastructure development

1986-90 vs 1976-80

2001-05 vs 1991-95
Infrastructure and inequality

• Improved access to infrastructure may have an especially large effect on the income of the poor
  – Basic setting: financial market imperfections that keep the poor from adopting efficiency-enhancing projects
  – Infrastructure development then helps by
    • Reducing the cost to access output and input markets (e.g., agricultural products; labor)
    • Helping entrepreneurship among those who can’t afford private substitutes for public infrastructure services
    • Facilitating human capital accumulation directly (water, sanitation effect on health) or indirectly (transport to school and health facilities)
Infrastructure and inequality

…but the result need not be invariably pro-poor

– E.g., infrastructure development may disproportionately benefit sectors intensive in high-skill labor (the case of ICT?)
– The form of infrastructure financing also matters

So what does the evidence say?

– Country-level studies with macroeconomic data
  • Relating infrastructure quantity and / or access to measures of income distribution (so reverse causality again an issue)
  • Tend to find pro-poor effects
– Studies of the effect of specific infrastructure projects on the income of the poor
  • E.g., rural roads (Peru, Vietnam, Bangladesh); irrigation (India) and electrification programs (South Africa)…
Inequality changes across regions due to infrastructure development (2001-5 vs. 1991-5 averages)

Changes in the Gini coefficient

-0.07 -0.06 -0.05 -0.04 -0.03 -0.02 -0.01 0.00 0.01 0.02

World Western Europe East Asia South Asia Middle East & North Africa Sub-Saharan Africa

Infrastructure Quantity Infrastructure Quality
The cost of infrastructure

For policy-making, the key question is: how much should be spent on infrastructure?

- Cost-benefit calculation: infrastructure spending crowds out other inputs – through higher taxes, wages, interest rates (or credit scarcity) – dampening the growth effect

The ‘Barro rule’: growth-maximizing spending as % of GDP equals the infrastructure elasticity of output ( = 10%)

- This holds exactly only in a very stylized theoretical setting
- However, the growth-maximizing level of spending exceeds its welfare-maximizing level: infrastructure takes time-to-build, and thus involves an additional consumption sacrifice.
The cost of infrastructure

In reality the growth effects of infrastructure spending depend on its efficiency – i.e., how it translates into assets. Spending efficiency shows large cross-country variation:

• In part, due to technical and physical factors
• But also reflecting institutional features
  – Technical capacity – project selection, implementation, evaluation
  – Governance conditions: budgetary and procurement practices, fiscal institutions, control of corruption
    • Weak governance raises *reported* ‘public investment’ – in reality, the cost of acquiring assets, not their quantity or quality
    • And encourages investment over O&M: bigger room for corruption, political favors and photo-ops.
Infrastructure investment and control of corruption
(cumulative investment 1980-2008, percent of 1985 GDP)
Unit cost of roads and control of corruption
(controlling for GDP per capita; 1980-2008)
Unit cost of main phone lines and quality of bureaucracy (controlling for GDP per capita; 1980-2008)
The cost of infrastructure

How does the efficiency of public infrastructure investment vary across countries?

• ‘Public Investment Management Index’: summary of four components related to different project stages:
  – Appraisal
  – Selection
  – Implementation
  – Evaluation

• Strongly correlated with overall institutional quality
<table>
<thead>
<tr>
<th>Country</th>
<th>Appraisal</th>
<th>Selection</th>
<th>Implementation</th>
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<th>Overall</th>
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*Note: The countries are ranked based on their performance in the Public Investment Management Index and its components.
Public investment efficiency, by country group
The cost of infrastructure

- The efficiency of infrastructure spending is key to its impact on growth and public finances
  - The higher efficiency, the larger the impact of a given amount of spending on income growth
  - And, given the government’s ability to collect taxes (or user fees), the more favorable the effect on future public revenues and the government’s solvency position.
Effect of an increase of public investment by 1 percent of GDP

5. High Efficiency (percent)

6. Low Efficiency (percent)

7. High Efficiency (percent of GDP)

8. Low Efficiency (percent of GDP)
Conclusions

• There is good evidence that infrastructure development makes a significant contribution to growth
  – Although the effect is much smaller than found in early literature
  – And the relative role of the various channels at work is less clear

• Also suggestive evidence of a positive impact on equity via enhanced economic opportunities for the poor
  – Hence potential scope for a double poverty-reducing effect

• The growth effect of infrastructure spending is largely shaped by fiscal institutions and overall governance
  – Low government capacity and weak governance inflate asset costs, discourage O&M, and reduce the efficiency of spending.
  – In many countries, reforms to increase the efficiency of spending should take higher priority than more spending
End
Additional slides
Infrastructure accumulation and growth
(1960-2000 country averages, percent)

\[ y = 0.505x + 0.0006 \]

\[ R^2 = 0.3253 \]

Growth in infrastructure stocks per worker

Growth in GDP per worker

Source: Calderón, Easterly and Servén (2003)
Infrastructure and growth

Calderón-Servén 2009: empirical growth framework augmented with physical measures of infrastructure
Synthetic index of telecom, transport and power
Also (noisy!) measures of quality of assets
Large panel dataset

Results:
- Infrastructure quantity and quality have robust growth effect – and economically significant.
- Not much evidence of heterogeneity (in log-log terms)
  • Across developing regions
  • Landlocked vs other countries
  • Related to infrastructure endowment (i.e., non-linearities)

Hence the marginal contribution of infrastructure development to growth is higher wherever quantity / quality are lower.
Infrastructure and growth

Calderón, Moral and Servén (2010): production function approach -- physical and human capital; infrastructure

• Focus on the contribution of infrastructure to labor productivity (GDP per worker)
• Synthetic infrastructure index (as before)
• 88 industrial and developing countries, 1960-2000 (> 3,500 obs)
• Closer look at heterogeneity of infrastructure contribution – both generic and along specific dimensions
  – Empirical framework allows intercepts, error variances and short-run dynamics to differ freely across countries.
  – Imposes (testable) cross-country homogeneity of long-run coefficients.
Infrastructure and growth

Main results

• Infrastructure elasticity in range .07 to .10 – and robust.
• Elasticities of other inputs (physical and human capital) in line with literature (around 0.35, 0.10 respectively)
• No evidence of (general) cross-country parameter heterogeneity
  – Accords with cross-country stability of factor shares (Gollin 2002)
• But country-specific estimates are noisy (especially in LICs), so tests may have low power. Test for specific forms of heterogeneity
  – By income level: infrastructure elasticity could differ in rich and poor countries
  – By level of infrastructure endowment: nonlinear effects of infrastructure (network effects?)
  – By population size: economies of scale / congestion effects.
  – By quality of policy framework: high / low distortions
Only this test comes close to 10% significance
Figure 4

Growth change under alternative infrastructure development scenarios

A. Catching up: halving the infrastructure level gap with other regions
B. Keeping up: matching the rate of infrastructure growth of other regions
Infrastructure investment and governance
(cumulative investment, percent of 1985 GDP)

- Weaker governance is associated with higher (reported) investment / GDP ratios (Tanzi-Davoodi 1997. Keefer-Knack 2007)
Unit cost of infrastructure assets and control of corruption (controlling for GDP per capita)

Power

Phone lines

Roads
Unit cost of infrastructure assets and quality of bureaucracy (controlling for GDP per capita)
Heat Map: Public Investment Management Index and its components
Financing infrastructure

• Public infrastructure projects typically involve a large upfront cost to acquire / build the assets
  – e.g., (half) infrastructure catch-up in Africa would require investment by 10% to 15% of GDP

• Over time, revenues eventually accrue from taxes on the enlarged income or from user fees

• Addressing big public infrastructure needs poses a fiscal challenge
Financing infrastructure

But two different fiscal dimensions to consider

- Short-run (liquidity): upfront investment costs lead to fiscal deficits – unless offset by other fiscal measures
- Long-run (solvency): over time, the upfront cost can be recovered (in part or in full) through increased revenues
- Infrastructure spending decisions need to take into account both dimensions – not just liquidity, as often done
  - Deficit reduction at the expense of infrastructure spending (as seen in LAC in the 80s and 90s) can be self-defeating
Infrastructure and *fiscal space*

Cash-flow targets distort the composition of spending

Net Worth line

Lower net worth
Worsened overall balance

Overall balance line
slope = -1
Financing infrastructure

• The efficiency of public infrastructure spending is key to its impact on public finances
  – The higher efficiency, the larger the impact of a given amount of spending on income growth
  – And for given government ability to collect taxes (or user fees), the more favorable the effect on future public revenues

• But the initial fiscal position matters too:
  – High debt and borrowing costs make higher taxes or reduced current spending preferable to debt finance of infrastructure
  – Low borrowing costs, high spending efficiency and revenue-raising ability can make infrastructure projects self-financing
Financing infrastructure

- Private sector involvement has become an increasingly important source of infrastructure financing
- Two different configurations: outright privatization and public-private partnerships (PPPs)
- Latin America has been at the forefront of private sector involvement – first through privatization in the 1990s, then through PPPs
- Private sector participation has been uneven across sectors – with telecom and power most favored
Infrastructure: Private investment commitments (by world region, US $ million)
Sector distribution of private investment commitments, 1990-2013

All regions

Latin America

- Energy
- Telecom
- Transport
- Water and sewerage
Infrastructure: private investment commitments (major Latin American countries, US $ million)
Financing infrastructure

• PPPs are often advocated as preferable to public provision on the belief that they free up public funds

• But in the long run they seldom do – they do not materially alter the government solvency constraint
  – what the government saves in initial investment expenditures, it has to make up through foregone tax or user fee revenue
  – PPPs are often motivated by the attempt to move infrastructure spending off the fiscal accounts – taking advantage of opaque fiscal accounting to sidestep deficit targets

• PPPs are superior only if they lead to efficiency gains
  – from bundling construction, maintenance and operation